Using in-vehicle avatars to prevent road violence

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ABSTRACT

The physical difficulty to express appropriate social interactions between drivers expresses itself in aggression, selfish driving and anti-social behaviour. By building computers that convey/understand social cues/context, technologists can dramatically improve collective decision making. Existing research on ITS has not capitalised on recent advances in social computing. Eye gaze is a social cue affecting collective decision making which could contribute substantially to safe driving. This preliminary study proposes a new unobtrusive in-vehicle system to communicate drivers' intentions and increase social awareness via eye gaze. Participants were asked to drive through different types of intersections, in a driving simulator. An avatar representing the head of the other driver was displayed and driver behaviour was analysed. The result has shown significant difference in terms of eye gaze pattern when an avatar is displayed. No changes have been observed in terms of speed. The proposed approach has the potential to improve social interactions between drivers, allow clearer collective decision making between road users and reduce the incidence of antisocial behaviour in the road environment.

Author Keywords

Road safety, Intelligent Transport Systems, avatars.

ACM Classification Keywords

H.1.2 [Models and Principles] User/Machine Systems – human factors; H.5.2 [Information Interfaces and Presentation] User Interfaces – Input devices and strategies, evaluation/methodology; K.4.1 [Computers and Society] Public Policy Issues: human safety

INTRODUCTION

Much of the emphasis in road safety in the last 50 years has been on modifying driver behaviour to reduce road crashes. Unfortunately, the effectiveness of these behavioural interventions in highly motorised countries has plateaued. Thus there is an urgent need to develop a novel type of intervention to reduce crashes.

This approach is simple, unconventional and radically different from traditional behavioural road safety interventions. It uses in-vehicle technology to mediate the social power of mutual gazes between road users to reduce road crashes. The technology mediates the subjective experience of being observed and sharing the road, even when the driver is physically and psychologically isolated in a vehicle. The driver is expected to change attitudes on his/her own to fulfil social norms (conformity theory [3]). Social norms are explicit or unspoken rules about how we ought to behave.

The system makes use of existing in-vehicle eye tracker technology to mediate the social power of mutual gazes between road users to reduce road violence, road hostility and selfish driving. This paper focuses on a pilot study examining the impacts of an avatar on driver's behaviour in a driving simulator. It examines two aspects of driver's driving behaviour namely eye gaze pattern and vehicle speed in the presence of avatars on intersections.

The reminder of this paper is structured as follows. A literature review is presented followed by the statements of the aims and the hypothesis of this study. Results of the experiment are discussed followed by a conclusion and limitations of the study.

LITERATURE REVIEW

Humans use eye gaze as an implicit rather than explicit or necessary, communication media. The social impact of eye contact on human behaviour has been documented in the literature:

Eye contact is a major social cue to driving safely: Argyle [1] has estimated that when two people converse, only 30% of the communication process is verbal, the other 70% is a result of indirect or nonverbal communication. Eye gaze direction plays a crucial role in the initiation and regulation of social encounters [9]. Being able to make eye contact is arguably one of the major foundations of social skills. Driving is a public and social behaviour where eye contact is a crucial cue enabling social awareness. Adopting a pro-social behaviour is commonly considered a good driving practice [8].

Eye contact breaks drivers' anonymity: The distance between drivers, the physical and psychological constraints imposed to perform the driving task safely, and vehicle design (metal frames, tinted windows) prevent drivers from exchanging clear and unambiguous social cues [15]. This hinders eye contact, isolates, provides a feeling of anonymity, and reduces drivers' social awareness. Individuals in anonymous situations often lose respect for themselves as well as others (disinhibition effect). Eye contact regulates social interactions and expresses a sense of intimacy [1]. It breaks anonymity, brings about self awareness and creates a feeling of immediacy and produces greater perception of closeness between individuals [4]. Research on immediacy and arousal has shown that eye contact causes the receiver to reciprocate positively with intimacy [13].

Eye contact communicates drivers' intentions: Knowing the intentions of other drivers is one of the informal road rules that drivers use to avoid crashes. Eye contact is a good predictor of attentional focus [1]. Social presence, the sense of being with another, may be the by-product of reading the intentions (minds) of others [12]. Eye gaze is one of the most potent nonverbal signals humans possess [18]. The best non-verbal way to communicate intentions with other road users is to attract their attention with eye contact [6]. This is a common safe practice for cyclists and pedestrians. Eye contact could serve to show concern for the other driver. Hence, the absence of eye contact between road users may indicate a lack of awareness of the presence of other road users.

Absence of eye contact as a social cue contributes to road violence: Road rage is a product of weakened social and personal controls, which can act in concert with arousal-inducing environmental circumstances, such as traffic congestion, work pressures, or family strain [15]. The inclination to undertake unsafe driving behaviour is exacerbated by the inability to perceive or express social cues when feeling anonymous. Inoffensive acts or gestures tend to be interpreted by angry drivers as aggressive and can escalate into road rage in an anonymous environment. It is widely acknowledged in the road safety community that being aware of being looked at has a tremendous effect on driver behaviour [15]. Social cues are important means to assess the acceptability of our own behaviour. The immediacy of human contact and the relative certainty that we would immediately and directly be called to account prevents us from undertaking anti social behaviour. The "presence" of eye contact is the most efficient way to improve the feeling of self-awareness [2].

Drivers who indicate too late or fail to indicate their intentions is among the top 5 most annoying behaviour [14]. While precise estimates on the cost and magnitude of aggression in road safety are not available. A figure from Australia has estimated that it is likely that driver aggression and related "selfish driving" contribute significantly to the approximately 11,000 rear-end crashes in the state of New South Wales (NSW) - Australia. This NSW's community between $286 and $638 million per year These behaviours are likely to also contribute to speeding, which is estimated to involve 40% of fatal crashes (Australian Institute of Criminology, May 2006- No 311).

Mediation of eye contacts with technology has positive social influence: Mediated eye contacts influence human behaviour. The positive effects of using eye gaze in the design of human computer interfaces has been demonstrated at length in the Immersive Virtual Environment, Human Computer Interactions and Computer-Supported Cooperative Work literature [18,4,5]. It has been shown that augmenting virtual characters such as avatars with eye gaze exerts a stronger social influence on human interactants [17,18]. An avatar is a digital model representing a human whose behaviour is driven by humans in real-time. An example of avatar is depicted in Figure 5. Avatars evoke a sense of social presence especially if they are anthropomorphic (human like) [12].

Context awareness, mediated interactions and driving task: Advances in in-vehicle technology to track eye gaze, head movement and vehicle dynamics allow the mediation of eye gaze between drivers who otherwise cannot establish eye contact.

Driving is a complex task in which the relevance of perceptual information is intrinsically linked to the driving context. Driving context includes information about the environment, vehicle and the driver. Context awareness computing is a way to improve drivers' awareness of the driving situation. Identifying what is the most relevant information in a given context is a challenging task in context modelling. For example, being aware of the eye gaze of other road users is very important at an unsignalised intersection; however it is not necessarily relevant when there are traffic lights. Intelligent Transport Systems (ITS) are increasingly used in vehicles to improve context awareness (e.g lane departure warning systems). Mechanisms to improve awareness of social cues such as eye gaze are increasingly used in Collaborative Virtual Environments (CVE). Unfortunately findings from the context awareness research community and CVE have not been transferred into road safety to reduce the burden of crashes and injuries.

Immersive Collaborative Virtual Environments (CVE) are simulations in which distributed users interact through digital media space. Unlike traditional video conference facilities, CVE track subtle non verbal social cues of interactants such as eye gaze and render them in real time onto avatars in order to improve social interactions. Eye contact is a primary aid to social interactions [1,9]. Any theory or account of social behaviour that fails to include eye gaze could be suggested to lack a critical element. The social influence of avatars featuring eye gazes and head movements monitoring have been shown in desktop environments [18]

Virtual agents has been shown to make a user pay more attention [1] and elicit emotions such as embarrassment or self–awareness [16]. The presence of a human or virtual human demonstrate classic social inhibition performance impairments effects compared to those performing alone [19,1]

AIMS

There has been little research into the role of social cues to improve driving behaviour. Existing theory on CVEs and avatars cannot be accommodated to a complex driving setting. Noticeable differences between the two types of situations, which have a fundamental impact on the design of the supporting technology, are *(i)* the driver "roughly" sees the other real driver but cannot necessarily perceive detailed social or emotional cues. *(ii)* eye contact patterns are relative to the driving situation and *(iii)* the driver shouldn't stare at the details to avoid visual distraction. Overall, existing CVE approaches lack the support for concise description, manipulation and models for reasoning about driving contexts.

Our overall objective of this research programme is to *improve drivers' social awareness by breaking the "shielded space"* with the use of an avatar with eye gaze movements. The avatar is designed to *maximize a sense of social presence by reducing anonymity and increasing intimacy and immediacy*.

HYPOTHESIS

This pilot study examines if the cited theory from social psychology and interactions in virtual environment are applicable in a driving simulator. We are testing three hypotheses which are:

- H_1. The presence of avatar's gaze has social influences on drivers' behaviour. Thus it is predicted that gaze and vehicle speed patterns will change when an avatar is present and that participants feel observed.
- H_2. Drivers are more cautious in the presence of avatar by seeking eye gaze information when it is available. It is predicted that eye gaze duration and eye glances towards the avatar will increase.
- H_3 The presence of avatar does not distract the driver. It is expected that the eye gaze duration on the avatar is below 1.6 seconds which is the maximum allowable according to the standard in-vehicle design guidelines.

EXPERIMENTAL DESIGN

This study identifies the driving behavioural changes resulting from the presence of an avatar by comparing the behaviour of each participant in situations with ("looking avatar") and without (4 cases) it. Eye gaze and head movements patterns are the only social cues that we display on the simulator's windshield as an avatar. The avatar embodies driver's eye gaze and head movement. The realism of the avatar is critical to elicit an experience of presence or to have the sensory experience of "being looked at". A "looking avatar" displayed on a windshield could generate a mere curiosity and be confounded with the expecting behavioural social effects (H_1). Therefore 4 other scenarios were created to try to isolate the effect of eye gaze from other confounding factors. The 5 scenarios display different type of icons:

- "Looking avatar"
  - A 3D rotating avatar turning dynamically towards the participant is displayed on top of the vehicle during encounters The avatar is displayed on the windscreen when the vehicle is in line of sight to minimise visual obstructions as represented in Figure 5.
- Other icons
  - "car" only: No icon is displayed on the top of the vehicle
  - "arrow": A 3D arrow is displayed on the top of the vehicle. The arrow was designed to be the same colour and same texture as the avatar shown in Figure 1.
  - Arrow "turning": A 3D arrow turning towards the participant is displayed on top of the vehicle Its rotation pattern is similar to the avatar's eye gaze.
  - "head": A 3D avatar identical to the "looking avatar" but looking constantly ahead and NOT at the participant.

Figure 1: Driving scenario with an icon (arrow).

Following one of the fundamental ideas of the underlying research project, avatars are only displayed above other vehicles in conflict situations, i,e. where collaborative decision-making is required. Conflicts could occur on intersections. Intersection-related crashes constitute more than 50 % of all crashes in urban areas and over 30 %in rural areas (Kuciemba and Cirillo, 1992) where 27% of road crashes occur. Our scenario features vehicles appearing from the left/right side of the intersections. A road signs indicate if participants have the right of way.

Driver's performance related to eye gaze, vehicle's speed, and acceleration/deceleration are recorded.

HARDWARE SETUP

Driver performance were measured with the SiVIC (Simulateur Véhicules–Infrastructure–Capteurs) driver simulator software, developed at the Laboratoire sur les Interactions Véhicules–Infrastructure–Conducteurs (LIVIC) of the Institut National de Recherche sur les Transports et leur Sécurité (INRETS), France and the FaceLab eyetracker . SiVIc and FaceLab logged data at 1Hz to 4Hz and 60Hz respectively.

The road scene is displayed with a projector. The vehicle is controlled with Logitech's MOMO steering wheel/pedals.. Acoustical inputs are provided by Logitech G5 (5.1) speakers. The simulator setup is shown in Figure 2.The participant's head is situated at a distance of approximately 150 cm from the screen, which has a width of 170 cm. Consequently, the field of view is limited to 30 degrees to either side, which coincides with the range in which the FaceLab eye tracker can detect accurately the exact eye gaze directions.

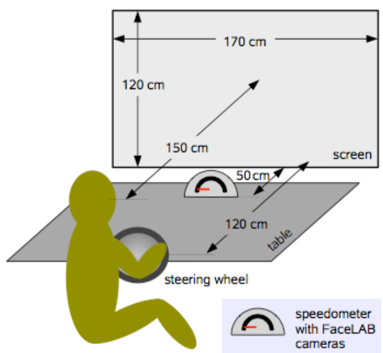


Figure 2 Simulator setup

Software were created to log and synchronise variables related to the environment, driver and road in an XML (eXtended Markup Language) database. Variables include acceleration, speed, lateral and longitudinal position, track curvature at the current position of the car, current 3D position of the icons and the crossing car in a camera-related coordinate frame, the object the avatar is gazing at, track index of the current position of the crossing car, speed of the crossing car, time of the encounter, the parameters of the current encounter (priority, side and type of icon), participant's eye gaze direction (relative to the scene and icons).

Driving Scenario

The residential roads have a width of 5 m in total. The roadway is composed of straight road modules featuring intersections separated by curves. The basic structure, shown in Figure 3, is repeated 32 times, providing for 96 intersections. Intersections create conflict situations. Conflict situations, are defined as instances of time in which two vehicles are bound to collide if they continue driving at their current speeds in their current directions of motion. We hypothesize that avatars fosters the resolution of conflict situations and, in turn, eliminates misunderstandings that might influence decision making. Misunderstandings could contribute to crashes or road violence such as verbal abuse.

The total distance is 13.4km. Intersections were designed to have different type of priorities:

- The participant has the priority referred as "main priority" (50 %): The participant has right of way, the crossing car stops to give way.
- Priority belongs to the crossing vehicle referred as "cross priority" (50 %): The crossing vehicle has right of way, i.e. the participant has to give way.

Vehicles approaching from right and left sides of these intersections are equal in numbers. The duration of the experiment is kept below 20 minutes.

Such a number of intersections allowed us to induce conflicts and observe consistent behaviour. Drivers are driving on the left side of the road.

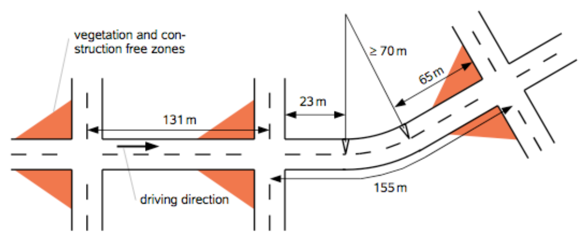


Figure 3 Road configuration

Bends affect the participants' ability to detect cars and associated icons in the simulator. The notion of outer and inner bends is shown in Figure 4 and will be taken into account during the analysis.

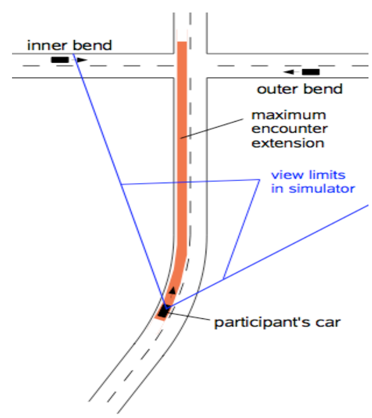


Figure 4: Influence of bends on visibility

Houses, vegetation and signs were placed on each side of the road to provide realistic features. Figure 5 shows such a driving environment.

Figure 5: Driving environment with avatar

Avatar's appearance and eye gaze

The avatar's appearance is anthropomorphic, but not photorealistic, and realistically imitates human visual behaviour. Graphical components such as houses and avatars were created as mesh objects with the Massive G (MG) 3D simulation and game engine. MG is open-source (GNU License) and relies on the OpenGL and Simple DirectMedia Layer (SDL) libraries.

The gaze duration, i.e. the total time the subject's eyes dwell inside a predefined window, also called detection window, during the encounter, is the central metric in evaluating the impact of the display of icons on drivers' gaze behaviour. Figure 13 shows two type of detection windows.

(a) looking straight ahead	(b) having turned to the left	(c) looking over 90 degrees left	(d) side view

Figure 6: Rotating avatar

Participants

12 researchers/students (8 males, 4 females, mean age = 28 years) from the Faculty of Health of the Queensland University of Technology participated in the study. Participants hold a driving license and have good eye sight.

PROCEDURE

Upon arrival, participants were briefed about the equipment to be used and the task. They were asked to drive normally and respect road rules. A researcher spent 7mn to calibrate the eyetracker on each participant. The researcher stayed in the room during the entire experiment. Participants had a 5-10 minutes practice where they encountered different type of situations (cars without avatars/with avatars not looking at them). The eyetracker were calibrated to each participant during the practice. The participants were asked to give general comments about the study at the end of the experiment.

RESULTS AND DISCUSSIONS

Factorial analysis of variance (Factorial ANOVA) is the statistical methods used to analyse the dependency of the variables such as speed, eye glances, eye gaze durations and type of displayed icon during encounters. The encounter zone covers approximately 30 meters before the end of each intersection. Eye gaze analysis are made in two stages. First analysis is performed on large square window including the icon and the vehicle. The second analysis is performed on smaller window including the icon only as shown in Figure 13.

Average speed relative to encounters

The average speed of the participants when approaching and crossing the intersections were measured before comparing the average speed in the presence of each icons.. Figure 7 summarizes the cases where participants have or do not the priority and a vehicle can appear from left or right. Figure 7 shows that, for main priority, velocities are independent of the side and considerably higher than for cross priority, where a difference between sides of approach is observed. The effect of the right of way situation is simply explained by the need to decelerate when giving way in the cross priority case, whereas no behavioural adaptation is required when the participant has right of way. The difference of speed relative to priority indicates that the participants see and respect road signs.

The ANOVA on the average speed yields significant main effects of priority ($F_{1,945}$=547,14, p<.001), side($F_{1,945}$=17.06, p<.001), as well as an interaction effect between priority and side ($F_{1,945}$=10.61, p=0.0012). The resulting model allows explanation of a considerable fraction of 38.7% of the observed variation in the average speed.

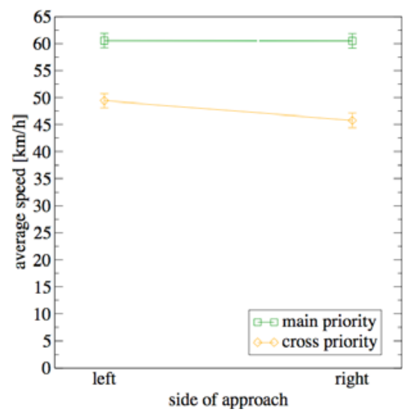


Figure 7: Interaction diagram of side and priority for average speed

The speed of the participants when presented with different icons did not show significant statistical difference. Such an observation could be interpreted as invalidating the H_1 hypothesis. However we will see later that it is not necessarily the case.

Detection time

The detection time, defined as the time elapsed from the moment the crossing car is launched to the onset of the first in a large window measures an important visual characteristic of the icons. It indicates the time taken to notice the crossing car. A shorter time indicates a better detection. The analysis of variance found 18.0% of the variation occurring in detection times is explained by the significant main effects of priority ($F_{1,925}$=121.09, p< .001), bend ($F_{2,925}$=21.64, p<.001), and side ($F_{1,925}$=28.83, p< .001), along with an interaction of priority with bend (($F_{2,925}$=5.32, p=0.0051). This fraction of explained variation can still be considered a fair result, given the imprecise eye tracker data.

Figure 8 shows that inner bend conditions entail longer detection times than both other road geometries, whereas the influence of outer bends compared to straight segments depends on priority. The effect of inner bends may trace back to the restricted field of view in the simulator. It should be noted that the use of an icon including "looking avatar" did not lead to a faster detection.

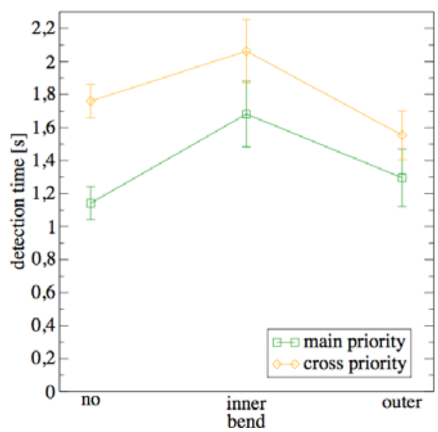


Figure 8: Interaction diagram of bend and priority for detection time

Gaze duration

The gaze duration, i.e. the total time the subject's eyes dwell inside the detection window during the encounter, is the central metric in evaluating the impact of the display of icons on drivers' gaze behaviour. For statistical analysis, the gaze duration has been normalised by individual's means. This normalization which yields the largest share of variability explained by the resulting model is motivated by substantial differences between subjects, which might conceal effects of the investigated factors. Values have been denormalised for presentation.

The analysis of variance performed on the normalised metric found the main effects of priority ($F_{1,941}$=112.02, p<.001), bend ($F_{2,941}$=11.77, p<.001), side ($F_{1,941}$=7.60, p=0.0059), and type ($F_{4,941}$=5.06, p=0.0005) to be statistically significant. 17.6% of the observed variation is explained by the resulting model.

The dependence of the gaze duration on the right of way situation and the side of approach is given by the interaction diagram in Figure 9. It exhibits a main effect of priority, the cross condition providing for longer gaze. This observation may be explained by the difference in encounter duration, as subjects pass the crossing vehicles at higher speeds in the main priority condition, leaving them less time to gaze at the crossing objects. Earlier detection of crossing vehicles in the case of main priority does not invalidate this explanation, since the "visibility phase" of the encounters, i.e. the encounter duration after accounting for the difference in detection times, is still longer for cross priority.

Considering the actual interaction, we see that, in the cross condition, gaze duration is substantially longer for vehicles approaching from the right. This may be explained by a combination of lower speeds of the participant's vehicle when they approach a crossing car on the closer lane, and the better visibility to the right due to the asymmetry of driving in the left lane, which allows for earlier detection of the crossing vehicle. A potential inclination of subjects to primarily check traffic on the lane they are about to enter first may amplify this effect. In case of main priority, an opposite effect of side is observed. It may partly be explained by the absence of a difference in encounter durations due to side in the main condition. Besides, drivers may pay less attention to objects further to the periphery of their field of view.

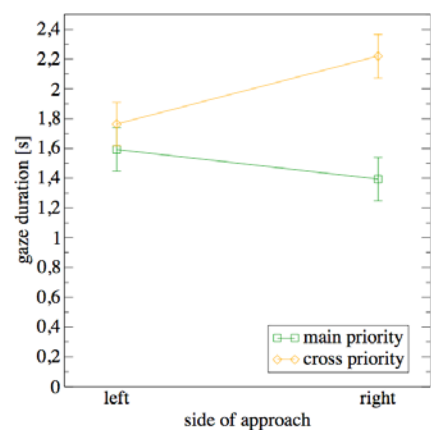


Figure 9: Interaction diagram of side and priority for gaze duration

The gaze duration is the first metric to show some dependency on the type of icon displayed above crossing cars. Statistically significant differences are observed between the avatar "looking" at the participant and the static icons ("arrow" and the avatar not turning towards the subject called "head") as well as the "car" only. The "looking" avatar exhibits the longest gaze duration. This supports the H_1 hypothesis and H_2 partially. The differences between the "turning" arrow and the static "arrow" as well as the "car" without any displayed icon are statistically significant. Considering the numerical differences provided in Figure 10 we find approximately three different levels allowing for two explanatory factors.

Both the static avatar and the arrow receive somewhat more gaze than the baseline case of a vehicle without icon. This is expected from theory since an abrupt onset, i.e. the sudden appearance of an object, in particular in a prominent position within the field of view, is supposed to attract visual attention. The same applies to a foreign, novel object not expected in the scene. Both characteristics apply to the icons, so they are expected to attract additional gaze.

The “turning” arrow and the “looking” head attract an additional share of gaze as compared to the static icons (“head” and “arrow”). This observation conforms to theory since a moving object is supposed to receive more visual attention. In particular for a dynamic task like driving, motion of objects is an important source of information, and visual resources are assigned accordingly. The fact that the effect of “turning” is statistically significant in contrast to the effect of appearance suggests that the former one is more reliable. Nonetheless, the sheer presence of an icon is not negligible, an object needing to be present in order to turn.

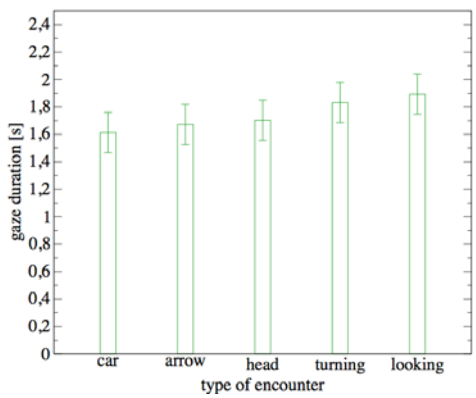


Figure 10: Dependency of gaze duration on the type of encounter (or icon)

Number of glances

The number of glances, i.e. the number of separate periods of time where the subject's gaze dwells inside the detection window featuring the vehicle and icon, has been included in the evaluation. An ANOVA yielded significant main effects for priority ($F_{1,945}$=178.79, p<.001) and bend ($F_{2,945}$=3.94), p=0.0199), along with an interaction of priority and side ($F_{1,945}$=30.11, p<0.001). The model additionally taking the main effect of side into account allows for an explanation of 18.2% of the observed variability. The type of the displayed icon has no significant effect on number of glances. Such finding supports the H_3 hypothesis as it indicates that the display of an avatar does not “disturb” the glance pattern.

The diagram of priority and side in Figure 11 shows trends similar to the gaze duration, which may explain why glance durations are largely independent of these explanatory factors. One may state that in case of cross priority, more glances at the crossing vehicle are required to negotiate the correct speed to pass behind it, an effect particularly prominent when the car approaches from the right, i.e. when the distance to potential collision is the shortest.

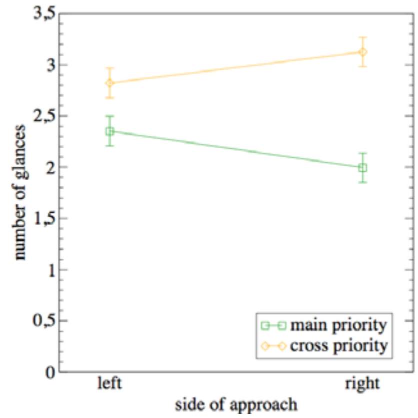


Figure 11: Interaction diagram of side and priority for the number of glances

Glance Duration

Glance duration is an important distraction metric. As such, its potential dependence on different icons or other parameters is of secondary importance, and it will be considered over all cases. In addition, the mean is not the only statistic of interest; devices attracting few, long glances may threaten traffic safety more than devices exhibiting slightly longer mean glance duration. Consequently, we are interested in the probability distribution of the glance duration, and in the percentage of glances exceeding some safety-critical threshold.

As an approximation of the probability distribution of the observed glance duration, the histogram is plotted in Figure 12. It shows that the majority of all glances are shorter than one second, the average being of 691 ms, below the threshold of 1.6s formulated in the Battelle Guidelines for on-road use of in-vehicle devices. The maximum glance duration of 2s postulated by the BSI guidelines is only exceeded by 2.32% of all glances, and a negligible fraction of 0.325% falls above 3s. Therewith, we can still consider the avatar or control object safe for on-road use, since they do not form a classical in-vehicle device requiring the driver to avert their gaze from the road when operating it. This supports the H_3 hypothesis. An additional features being projected onto the road environment, the requirements in terms of maximum glance duration can be relaxed, since drivers still perceive the traffic environment by means of peripheral view while looking at the icon.

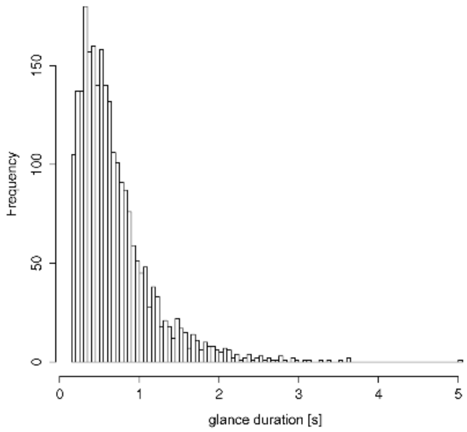
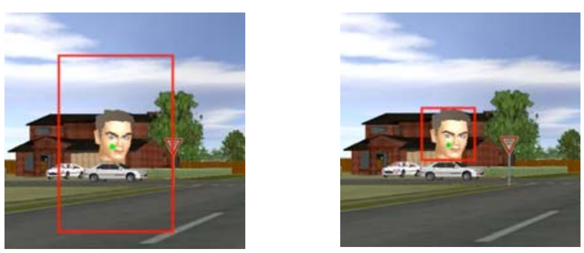


Figure 12: Histogram of glance durations

DETAILED ANALYSIS FOR A SUBSET OF PARTICIPANTS

The results presented in previous sections were based on gaze metrics captured in large detection windows. This section uses a small window as illustrated in Fig 13-b. The gaze directed at the icon itself is of fundamental interest for this study aiming at the evaluation of the impact of the type of icons on drivers' gaze behaviour. Unfortunately, the metric expressing the amount of this gaze, the gaze duration inside the small window, is plagued by eye tracker errors, which additionally required the restriction of the set of participants. We have selected the participants with the most accurate eye tracking results (N=5). Explanatory metrics are reiterated for the subset of participants. Despite these limitations, which may particularly impact on the generalisability of the results, some intriguing effects are revealed by statistical analysis.



(a) large window (with error margins) (b) small window

Figure 13: Detection windows

Average speed

The problem of small sample sizes is the lack of statistical power, i.e. statistically significant differences are more difficult to be obtain, since it requires larger numerical effects. Therefore, it is little surprising that an ANOVA only found two significant main effects explaining the average speed during the encounters: Priority ($F_{1,312}$ =95.49, p <0.001) and phase ($F_{2,312}$ =6.38, p =0.0019). However, the model still allows explanation of 25.0% of the observed variability.

The dependency of the average speed on the right of way situation given in Figure 14 is consistent with the observation for all participants and allows for the same explanation: When having to give way, subjects need to adapt their velocity to pass behind the crossing vehicle, resulting in lower average speeds.

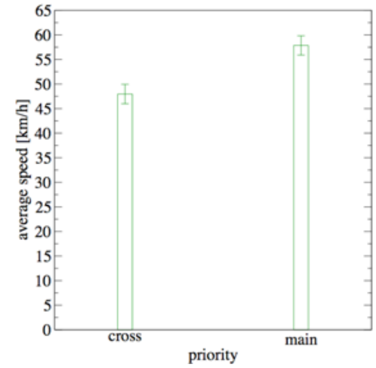


Figure 14: Dependency of average speed

Gaze duration

Like for the gaze duration in large windows covering the car and the icon, normalisation with respect to participants and with respect to encounter duration has been considered for the gaze duration in small windows. Unlike in the former case, normalisation by the encounter duration provided for the most suitable model in terms of explained variability. Therefore, the analysis of variance is done on the normalised metric, and resulting predictions have been de-normalised by multiplication by the grand mean of encounter durations for presentation.

The implication that small-window gaze durations depend on the encounter duration, while gaze durations for the large windows do not, suggests some valuable interpretations. On the one hand, longer encounter durations tend to coincide with lower velocities of the participant's car, and independently thereof, are likely to leave the subject more time to react to the traffic situation. Accordingly, extended gazing at the avatar or control object can be considered a luxury only possible in potentially less demanding or less stressing situations. This is partly due to a decrease in the need for gaze at the crossing vehicle under such conditions, since the duration of gaze at the combination of icon or car, being less influenced by the encounter duration, seems dictated by the driving manoeuvre rather than by the demand of the concrete situation. Reformulating the argument, one could say that participants focus their attention on the icon giving additional information when they have the time to do so. Otherwise, i.e. if essential information for driving decisions in a potentially tense situation is likely to be required, they fall back to the unambiguous standard source of such information -- the crossing vehicle.

On the other hand, however, the dependence of the duration of gaze at the target on the encounter duration may also trace back to the experimental situation. When encounters are long (in time), chances are that participants already see the combination of vehicle and icon from far. In this case, the avatars and control objects of constant size are a more likely target of gaze than the distant car, which then appears relatively small on the screen. If the encounter is short and the crossing vehicle thus likely to be detected when it is already close, its projection on the screen is considerably larger and may therefore attract more gaze than the icon.

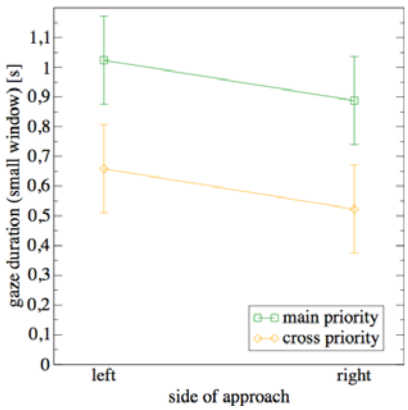


Figure 15: Interaction diagram of side and priority for gaze duration in small windows for subset of subjects

Besides this preliminary analysis, the influence of the encounter parameters is of particular interest. The ANOVA performed on the usual set of factors found 16.1% of variance explained by the three main effects of priority ($F_{1,310}$=34.61, p < .001)), side ($F_{1,310}$=5.04, p=0.0255), and type of icon ($F_{1,310}$=8.57, p< .001).

There is a considerable main effect of priority, unlike for gaze at both car and icon (i.e. in the large window) by the subset of participants. This suggests that participants, while attributing equal amounts of visual attention to the approaching objects (i. e. vehicle and icon) in both priority conditions, spend a larger share of this attention on the icon when they have right of way. This fact allows for an interpretation favorable for the idea of communicating drivers' intentions by means of avatars: When having right of way, the crucial information drivers need is whether the crossing car is going to slow down in order to give way, as demanded by the road signs. That is, information on the other driver's intention is required, and apparently participants referred to the icon in these cases. When having to give way, in contrast, the crucial information drivers need is the relative distance and speeds of the crossing car in order to adapt their velocity to pass behind the other vehicle. Such information is more precisely obtained by gazing at vehicle itself, i. e. by the real object in the natural environment, rather than by the – artificial – icon which is additionally displayed. Accordingly, a larger fraction of gaze is attributed to the vehicle in the cross priority condition.

Figure 16 depicts the impact of the 4 type of displayed icon on the gaze duration. Differences between the "looking" avatar and all other cases are statistically significant, as is the difference between the static "arrow" and the "turning" arrow.

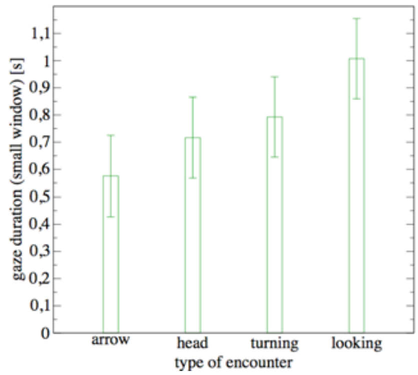


Figure 16 Dependency of gaze duration of the subset of subjects in small windows on the type of icon

As expected, a significant effect of movement is observed for both the "looking" avatar and other control icons. There is also an – at least numerical – effect of the type of icon, the humanoid avatar attracting more gaze. This supports H_1 hypothesis and still complies with the in-vehicle design requirements in terms of distraction (H_3).

CONCLUSION

27% of crashes in the US occur on intersections. 80% of them are due to human errors where (i) lack of awareness of the presence of others or (ii) lack of knowledge of the others intentions are contributing factors. We introduced new techniques for conveying social/intentional information through avatars with the view to improve situational awareness and decision making. Extensive research is needed to show that in-vehicle avatars can objectively reduce road rage and improve road safety. However this preliminary study laid the basis for such future study. It showed the 3 hypotheses are verified.

H_1: The presence of avatar's gaze has social influences on drivers' behaviour.

- Though no proof for their occurrence, the longer gaze durations to looking avatars are coherent with the assumption of the existence of eye contacts. The perception of being looked at was reported by a majority of participants supports this assumption.

H_2: Drivers are more cautious in the presence of avatar by seeking eye gaze information when it is available

- There is no indication showing that drivers slow down in the presence of avatar. However there are some indications that drivers refer to the avatar when needing information on the intention of others.

H_3: The presence of avatar does not distract the driver

- The number of glances and time spent gazing at the avatar does not indicate an unsafe distraction by standards of in-vehicle device design and is not expected to increase driver’s workload.

- Avatars seem to be consulted primarily in less demanding driving situations, which underlines their non-distractive nature.

LIMITATIONS

This driving simulator study is a simplified version of the complex real world situation. It lacks the social context provided by a naturalistic condition. Unfortunately, a naturalistic study was not feasible due to safety reasons. Therefore caution should be taken in extrapolating the validity of this preliminary study to real driving conditions. Furthermore, the small sample size and representativeness limits the expressiveness and robustness of results. With respect to the experiment, the random order in which the icons were presented may have limited effects as the participants could not get habituated to the presence of the same icon. Lastly, as many in-vehicle sensors, the eyetracker introduces spatial imprecision and delay when synchronized with the driving simulator events. Such errors could affect the quality of the analysis.

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